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(54) METHOD OF COATING A MOVING METAL STRIP

(71) We, JOHN SUMMERS & SONS LIMITED, a British company, of Hawarden Bridge Steelworks, Shotton, Deeside, Flintshire, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention concerns a method of coating a moving metal surface, particularly a moving metal strip.

According to the present invention, there is provided a method of coating a moving metal surface comprising forming a dry layer of metallic powder on the surface, thereafter applying a liquid to the said layer, and then passing the layer against a compression roller to compact the powder to the said surface, the said liquid being such as to reduce the extent to which the roller dislodges the powder.

The said surface may be the surface of a moving metal strip there being provided a co-operating pair of said compression rollers through the nip of which the strip is passed.

Preferably the layer is dried after the liquid is applied, before being passed against the said roller or rollers.

The said liquid may be an aqueous colloidal solution of a substance which gels when suitably hydrated.

The liquid may be an aqueous colloidal cellulosic solution.

Thus the liquid may be an aqueous solution containing sodium carboxy methyl cellulose.

Preferably the concentration of the sodium carboxy methyl cellulose in the solution is not less than 0.05% nor more than 0.6% by weight.

In a preferred embodiment, the said concentration is not less than 0.2% nor more than 0.4%.

Alternatively the solution may contain starch, at a concentration between 0.2% and 1% by weight.

Alternatively the solution may contain Bentonite, at a concentration of not less than 0.5% nor more than 2% by weight.

Alternatively the solution may contain aluminium hydroxide or nickel hydroxide at a concentration of not less than 0.05% nor more than 1% by weight.

Preferably the liquid is applied to the surface at a rate between 2 cubic centimetres and 4 cubic centimentres per square foot of surface.

The invention also provides a metal article having a surface coated by the method set forth above.

The invention is illustrated, merely by way of example, in the accompanying drawing which shows an apparatus which may be employed to coat a moving metal strip in accordance with the method of the present invention.

In the drawing, there is shown an apparatus comprising an uncoiler 1 which carries a roll 2 of mild steel strip 3. The strip 3, which is uncoiled from the roll 2, passes over two spaced apart guide tables 4, 5. Between the tables, 4, 5 there is disposed a shear 6 which may be operated, by means not shown, to shear the strip 3 as required.

After leaving the table 5, the strip 3 may pass along a cleaning line (not shown) which may comprise a degreasing bath, where the strip may be subjected to a degreasing liquid while being scrubbed, a cold water rinse, a pickling bath, and a further cold water rinse.

After passing through the cleaning line, the strip 3 passes through a bath 7, squeegee rolls 8, and sprays 9 which collectively constitute a wetting station. The bath 7 and the sprays apply to the opposite surface of the strip 3 a solution containing sodium silicate (or, alternatively, potassium silicate) e.g. in a concentration of 1.0 to 5.0 (and preferably of 3) grams of sodium silicate per litre of water. The sodium silicate may be a commercial sodium silicate containing 18% w/w sodium oxide, and 36% w/w of silica.

The bath 7 and squeegee rolls 8 are provided in order to ensure that the strip has already been thoroughly wetted with the sodium or potassium silicate solution before

being sprayed therewith, whereby to obtain a more uniform film of the said solution on the strip.

The sprays 9 may subject the opposite surfaces of the strip 3 to the said solution in an amount from 0.75 to 2.5 and preferably about 1.5 cubic centimetres of the said solution for each square foot of the adjacent surface. This amount of solution is such as to trap the powder which is subsequently applied to the strip while being insufficient to cause pools of the solution to build up on the strip.

After leaving the wetting station 7—9, the strip 3 then passes through a first powder application station constituted by two powder deposition units 10 mounted above the strip 3. The powder deposition units 10 apply aluminium (or other metallic) powder to the upper surface of the strip 3. Each of the powder deposition units 10 comprises a porous meter roll 11 having peripheral pockets (not shown) which are supplied with powder from a hopper 12. The powder in the said pockets is blown by a stream of air or other gas towards the upper surface of the strip 3. The powder passing towards the upper surface of the strip 3 passes through electrostatically charged screens 13, the voltage applied to the screen being, for example, approximately 20,000 volts for each inch of distance between the bottom of the screens 13 and the strip 3.

The aluminium powder thus falls in an electrostatically charged condition onto the adjacent surface of the strip 3 where it would normally lose its charge and be re-attracted back upwardly were it not trapped by the sodium or potassium silicate solution on the strip. The potassium or sodium silicate, moreover, prevent oxidation or other corrosion of the aluminium powder by the water in the said solution.

The strip 3, which has been so coated, then passes above two powder deposition units 14 which constitute a second powder application station at which the aluminium (or other metallic) powder is applied to the lower surface of the strip. Each of the powder deposition units 14 comprises a porous meter roll 15 having peripheral pockets (not shown) which are supplied with powder from a hopper 16, the powder in the said pockets being blown towards the underside of the strip 3 by air or other gas reaching the inner surface of the meter roll 15 through a fluid conduit 17. The meter rolls 15 and strip 3 are earthed, the powder from the meter rolls 15 which is directed towards the strip 3 passing successively through electrically conducting screens 20, 21 of which the screen 21, which is that nearer to the strip 3, is maintained (by means not shown) at a negative or positive potential e.g. a potential of -30 kv. The screen 20, which is that nearer to the meter roll 15, is electrically isolated, but may have an electrostatic charge, e.g. of -10 kv., induced in it.

The construction of the powder deposition unit 14 is more fully described in our co-pending patent applications Nos. 57096/67 (Serial No. 1203471) and 57098/61 (Serial No. 1203472).

After passing successively through the wetting station 7—9, the first powder application station 11, and the second powder application station 14, the strip passes to a first drying station 22, at which each of the surfaces of the strip is dried by passing the strip through a high frequency heater. As a result the sodium silicate remaining on the strip acts as a binder which prevents the aluminium powder from falling off the strip.

The strip 3 then passes between sprays 23, 24 which constitute a liquid application station at which the upper and lower surfaces of the strip are wetted with a liquid whose purpose is indicated below.

Thereafter, the strip 3 passes through a second drying station 25 and then a rolling mill 26 which constitutes a compaction station, the rolling mill 26 having rollers 27, 28 between which the strip passes and which compact the aluminium coating to both the surfaces of the strip. The strip 3 is finally coiled onto a roll 30 of a coiler 31 from which it is removed to be heat treated at an elevated temperature e.g. by being heated at 500°C for 1 hour, or by being heated at 350°C for 15 hours.

The aluminium powder applied to the strip is typically that which passes a B.S. 410 No. 300 mesh sieve. The powder is dispensed by the powder deposition units 10 such that the powder contains a high percentage of "fines" e.g. the powder contains 30 to 40% of particles less than 20 microns and 10 to 15% of particless less than 10 microns.

While this powder gives a good quality coating to the strip, it has very poor flow properties. Consequently, if the strip is passed through the rollers 27, 28 at more than a moderate speed the powder is dislodged and banks of dislodged powder build up immediately ahead of the rollers.

It is to combat this problem that the sprays 23, 24 are provided. By means of the sprays 23, 24, a liquid is applied on top of the layer of powder on the strip, the liquid being such as to reduce the extent to which rollers dislodge the powder.

The liquid applied to the strip by the sprays 23, 24 may be an aqueous colloidal solution of a substance which gels when suitably hydrated. Examples of such substances are nickel hydroxide, aluminium hydroxide, or a water soluble cellulosic material such as sodium carboxy methyl cellulose.

As a result of the wetting by the liquid from the sprays 23, 24, the strip may pass at, for example, 60 ft. per minute or even

100 ft. per minute, whereas if this wetting is omitted, it may be necessary to limit the speed of the strip to, say, 30—35 ft. per minute.

The sprays 23, 24 may be such as to apply from 2.0 to 4.0 (and preferably about 3.0) cubic centimetres of solution per square foot of surface to each side of the strip. When sodium carboxy methyl cellulose is employed, the concentration thereof in the said solution should be within the range of about 0.05% to 0.6% by weight of the solution. Preferably, the concentration is not less than 0.2% nor more than 0.4% by weight.

When aluminium hyroxide or nickel hydroxide is employed, the concentration of the solution preferably is within the range 0.05% to 1% by weight. Another substance that has been successfully used is starch in an aqueous colloidal solution of a concentration not less than 0.2% nor more than 1% by weight. The concentration is preferably 0.5% by weight.

Bentonite is also satisfactory when used in an aqueous colloidal solution of concentration not less than 0.5% nor more than 2% by weight. The concentration is preferably 1% by weight.

The following experimental results illustrate the effect of applying a suitable liquid via the sprays 23, 24.

TABLE I

Results obtained without the application of a suitable liquid via sprays 23, 24

STEEL STRIP — 0.040" thick coated on both sides with the aluminium powder to produce a compacted coating 40 microns thick.

Pre-wetting by sprays 9 on steel prior to powder application	Maximum strip speed through rolls Ft/Min	Adhesion of layer after Compaction & Heat treatment
Water 1.5 cc/sq.ft.	15	Good
„ 4 cc/sq.ft.	17	Good
„ 6 cc/sq.ft.	Too wet — powder runs into pools	—
3 gms/litre of Aqu.soln. of sodium silicate 2cc/sq.ft.	25	Good
6 gms/litre — do — 2 cc/sq.ft.	35	Fair
0.2% Sodium carboxyl methyl cellulose soln. 2 cc/sq.ft.	40	Fair
0.3% — do — 2 cc/sq.ft.	60	Poor
0.5% — do — 2cc/sq.ft.	100*	Poor
*Speed limit of Plant.		

This table illustrates that increasing the concentration of the sodium silicate binder applied via the sprays 9 enables the roll speed to be increased, but it reduces unacceptably the adhesion between the coating and the substrate after heat treatment. The table also illustrates that a solution containing sodium carboxy methyl cellulose can be applied via the sprays 9 instead of sodium silicate. The maximum concentration of sodium carboxy methyl cellulose acceptable is about 0.2% by weight. However, it can be seen that the use of sodium carboxy methyl cellulose has the same disadvantages as indicated for sodium silicate. We have found however that increased concentrations of sodium silicate or particularly sodium carboxy methyl cellulose may be advantageous in that the layer of powder is less likely to be dislodged before compaction due to vibration of the steel strip.

We think that the more concentrated solutions applied via the sprays 9 cause poor adhesion of the coating to the substrate after heat-treatment by contaminating the interface therebetween.

In order to increase the speed of the strip without reducing the adhesion of the coating to the strip after heat treatment, we effected

trials in which instead of increasing the concentration of the solution applied via the sprays 9, a suitable liquid such as indicated previously was sprayed on top of the dried powder coating, by means of the sprays 23, 24 mentioned above. Table 2 indicates the results obtained.

TABLE 2

Results obtained with the application of a suitable liquid via sprays 23, 24.

STEEL STRIP — 0.040" thick coated on both sides with the aluminium powder to produce a compacted coating 40 microns thick.

Pre-wetting by sprays 9 on steel prior to powder application	Post-wet Liquid applied by sprays 23, 24	Maximum strip speed through rolls Ft/min.	Adhesion of layer after Compaction & Heat treatment
Water	0.2% Sodium carboxy methyl cellulose 3cc/sq.ft.	35	Good
"	0.4% —do— 3cc/sq.ft.	60	Good
Sodium Silicate	0.2% —do— 3cc/sq.ft.	40	Good
"	0.4% —do— 3cc/sq.ft.	100	Good
"	0.5% colloidal soln. of starch 3cc/sq.ft.	50	Good
"	1% colloidal soln. of of Bentonite 3cc/sq.ft.	50	Good
"	0.5% colloidal soln. nickel hydroxide 3cc/sq.ft.	60	Good

We are of the opinion that the powder layer acts as a filter for the solutions applied via the sprays 23, 24. Two mechanisms appear possible. Either the powder layer absorbs water from the solutions so that the remaining solution either gels or becomes too viscous to flow to the layer-to-substrate interface. Alternatively, the powder layer filters out the solids in the solution and allows only water to approach the interface.

We think that the filtered-out or gelled material at the surface of the powder layer glazes the surface thereof to bind the powder particles together.

It is desirable both to dry the strip, at the first drying station 22, prior to having the said liquid applied to it, and also to dry the strip at the second drying station 25 prior to the strip passing to the compaction station 26.

Other liquids which should prove to be successful are solutions containing gum arabic or gum tragacanth or naturally occurring colloids, e.g. albumin, globulins, many cellulosic materials, e.g. cellulose, starch, amylose, pectin and salts of alginic acid, polyvinyl alchol. Globulins are a group of naturally occurring simple proteins which contain glycine, e.g. vegetable globulin. A common property of such materials is that they rapidly lose their mobility if water is removed from the solution. Another property is that a relatively low solid content is required to produce high viscosity. This means that the amount of contaminant in the upper layers of the powder coating is relatively small and will not prevent the compacted powder from sintering.

As will readily be seen from the drawing, the wetting station 7—9, the first powder application station 11, the second powder application station 14, the first drying station

22, the liquid application station 23, 24, the second drying station 25, and the compaction station 26 are absolutely in line with each other so that the strip 3 when passing through these stations does not have its direction of travel altered. Furthermore, it will also be seen that the uncoiler 1 and the coiler 31 are also substantially in line with the various stations 7—9, 11, 14, 22, 23, 24, 25 and 26. This arrangement reduces the number of guide rolls over which it is necessary for the strip 3 to pass, and therefore reduces the extent to which dirt can readily be picked up by the strip 3. It is very desirable to limit transference of dirt to the strip, since such dirt can have an adverse effect upon the adhesion developed between the coating and the strip during the final heat treatment.

The alignment of all the various stations, moreover, reduces to a minimum the amount of strip which is passing through the apparatus at any one time, this being desirable if high losses are to be prevented during temporary shut-downs of the apparatus .

It will be appreciated that the invention can be employed to coat moving metal surfaces other than the surfaces of a strip. For example, wire or rod can be similarly coated.

In our copending Application 56871/67 we have described and claimed a method of coating a moving metal strip comprising uncoiling the strip from an uncoiler, wetting each side of the strip, applying metallic powder to both sides of the wet strip, drying each side of the wetted and powdered strip, compacting the metallic powder to each side of the strip, and coiling the strip onto a coiler for subsequent heat treatment to bond the powder to strip, the wetting, powder applying, drying and compacting operations being performed at spaced apart stations, the uncoiler, all the said stations and the coiler being in a straight line, the uncoiled strip passing through the said stations without having its direction of travel altered.

WHAT WE CLAIM IS:—

1. A method of coating a moving metal surface comprising forming a dry layer of metallic powder on the surface, thereafter applying a liquid to the said layer, and then passing the layer against a compression roller to compact the powder to the said surface, the said liquid being such as to reduce the extent to which the roller dislodges the powder.

2. A method as claimed in claim 1 wherein the said surface is the surface of a moving metal strip there being provided a co-operating pair of said compression rollers through the nip of which the strip is passed.

3. A method as claimed in claim 1 or 2 wherein the layer is dried after the liquid is applied, before being passed against the said roller or rollers.

4. A method as claimed in any preceding claim wherein the said liquid is an aqueous colloidal solution of a substance which gels when suitably hydrated.

5. A method of coating as claimed in claim 4 in which the liquid is an aqueous colloidal cellulosic solution.

6. A method of coating as claimed in claim 5 wherein the liquid is an aqueous solution containing sodium carboxy methyl cellulose.

7. A method as claimed in claim 6 wherein the concentration of the sodium carboxy methyl cellulose in the solution is not less than 0.05% nor more than 0.6% by weight.

8. A method as claimed in claim 7 wherein the said concentration is not less than 0.2% nor more than 0.4%.

9. A method as claimed in claim 4 wherein the solution contains starch, at a concentration between 0.2% and 1% by weight.

10. A method as claimed in claim 4 wherein the solution contains Bentonite at a concentration of not less than 0.5% nor more than 2% by weight.

11. A method as claimed in claim 4 wherein the solution contains aluminium hydroxide or nickel hydroxide at a concentration of not less than 0.05% nor more than 1% by weight.

12. A method as claimed in any preceding claim wherein the liquid is applied to the surface at a rate between 2 cubic centimetres and 4 cubic centimetres per square foot of surface.

13. A method of coating a moving metal surface, comprising the steps of forming a dry layer of metallic powder on the surface, thereafter applying a liquid to the said layer, and then passing the layer against a compression roller to compact the powder to the said surface, the said liquid being such as to reduce the extent to which the roller dislodges the powder, the said steps being substantially as herein described.

14. A metal article having a surface coated by the method of any of claims 1 to 13.

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1,214,159 COMPLETE SPECIFICATION

1 SHEET

This drawing is a reproduction of the Original on a reduced scale.